# Pseudomonas aeruginosa

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***Pseudomonas aeruginosa*** is a Gram-negative, aerobic, rod-shaped bacterium with unipolar motility.[1] An opportunistic human pathogen, *P. aeruginosa* is also an opportunistic pathogen of plants.[2] *P. aeruginosa* is the type species of the genus *Pseudomonas* (Migula 1894).[3]

*P. aeruginosa* secretes a variety of pigments, including pyocyanin (blue-green), fluorescein (yellow-green and fluorescent, now also known as pyoverdin), and pyorubin (red-brown). King, Ward, and Raney developed Pseudomonas Agar P (aka King A media) for enhancing pyocyanin and pyorubin production and Pseudomonas Agar F (aka King B media) for enhancing fluorescein production.[4]

*P. aeruginosa* is often preliminarily identified by its pearlescent appearance and grape-like odor *in vitro*. Definitive clinical identification of *P. aeruginosa* often includes identifying the production of both pyocyanin and fluorescein as well as its ability to grow at 42°C. *P. aeruginosa* is capable of growth in diesel and jet fuel, where it is known as a hydrocarbon-utilizing microorganism (or "HUM bug"), causing microbial corrosion. It creates dark gellish mats sometimes improperly called "algae" because of their appearance.

Although classified as an aerobic organism, *P. aeruginosa* is considered by many as a facultative anaerobe as it is well adapted to proliferate in conditions of partial or total oxygen depletion. This organism can achieve anaerobic growth with nitrate as a terminal electron acceptor, and in its absence it is also able to ferment arginine by substrate-level phosphorylation. Adaptation to microaerobic or anaerobic environments is essential for certain lifestyles of *P. aeruginosa*, like during lung infection in cystic fibrosis patients where thick layers of alginate surrounding bacterial mucoid cells can limit the diffusion of oxygen. [5] [6] [7] [8] [9]

***Pseudomonas aeruginosa***

*P. aeruginosa* on an XLD agar plate.

**Scientific classification**

| | |
|---|---|
| Kingdom: | Bacteria |
| Phylum: | Proteobacteria |
| Class: | Gamma Proteobacteria |
| Order: | Pseudomonadales |
| Family: | Pseudomonadaceae |
| Genus: | *Pseudomonas* |
| Species: | ***aeruginosa*** |

**Binomial name**

***Pseudomonas aeruginosa***
(Schröter 1872)
Migula 1900

**Type strain**

ATCC 10145

CCUG 551
CFBP 2466
CIP 100720
DSM 50071
JCM 5962
LMG 1242
NBRC 12689
NCCB 76039
NCIMB 8295
NCTC 10332
NRRL B-771
VKM B-588

**Synonyms**

*Bacterium aeruginosum* Schroeter 1872
*Bacterium aeruginosum* Cohn 1872
*Micrococcus pyocyaneus* Zopf 1884
*Bacillus aeruginosus* (Schroeter 1872) Trevisan 1885
*Bacillus pyocyaneus* (Zopf 1884) Flügge 1886
*Pseudomonas pyocyanea* (Zopf 1884) Migula 1895
*Bacterium pyocyaneum* (Zopf 1884) Lehmann and Neumann 1896
*Pseudomonas polycolor* Clara 1930
*Pseudomonas vendrelli nomen nudum* 1938

## Contents



## Nomenclature

- The word *Pseudomonas* means "false unit", from the Greek *pseudo-* (Greek: ***ψευδο*** 'false') and *monas* (Latin: ***monas***, from Greek: ***μονος*** 'a single unit'). The stem word *mon* was used early in the history of microbiology to refer to germs, e.g. Kingdom *Monera*.

- The species name *aeruginosa* is a Latin word meaning "copper rust" as seen with the oxidized copper patina on the Statue of Liberty. This also describes the blue-green bacterial pigment seen in laboratory cultures of *P. aeruginosa* (a common abbreviation of the scientific name). This blue green pigment is a combination of two metabolites of P. aeruginosa, pyocyanin (blue) and pyoverdine (yellow) which impart the blue green characteristic color of P. aeruginosa cultures. Pyocyanin biosynthesis is regulated by quorum sensing as in the [[biofilm]s associated with *P. aeruginosa*'s colonization of the lungs of cystic fibrosis patients. Alternatively, it may be derived from the Greek prefix *ae-* meaning "old" or "aged" and the suffix *ruginosa* means 'wrinkled or bumpy'. [10]

- The prefix *pyo-* meaning pus (Greek) and *-cyanin* meaning blue. As with pyocyanin, the prefix of pyoverdine *-pyo* means pus, while *-verdine* means green. However, pyoverdine in the absence of pyocyanin, actually a fluorescent yellow color.

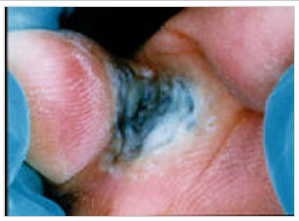
## Genomic diversity

The G+C rich *Pseudomonas aeruginosa* chromosome consists of a conserved core and a variable accessory part. The core genomes of *P. aeruginosa* strains are largely collinear, exhibit a low rate of sequence polymorphism and contain few loci of high sequence diversity, notably the pyoverdine locus, the flagellar regulon, *pilA* and the O-antigen biosynthesis locus. Variable segments are scattered throughout the genome of which about one third are immediately adjacent to tRNA or tmRNA genes. The three known hot spots of genomic diversity are caused by the integration of genomic islands of the pKLC102 / PAGI-2 family into $tRNA^{Lys}$ or $tRNA^{Gly}$ genes. The individual islands differ in their repertoire of metabolic genes, but share a set of syntenic genes that confer their horizontal spread to other clones and species. Colonization of atypical disease habitats predisposes to deletions, genome rearrangements and accumulation of loss-of-function mutations in the *P. aeruginosa* chromosome. The *P. aeruginosa* population is characterized by a few dominant clones widespread in disease and environmental habitats. The genome is made up of clone-typical segments in core and accessory genome and of blocks in the core genome with unrestricted gene flow in the population.[11]

## Cell-surface polysaccharides

Cell-surface polysaccharides play diverse roles in the bacterial "lifestyle". They serve as a barrier between the cell wall and the environment, mediate host-pathogen interactions, and form structural components of biofilms. These polysaccharides are synthesized from nucleotide-activated precursors and, in most cases, all the enzymes necessary for biosynthesis, assembly and transport of the completed polymer are encoded by genes organized in dedicated clusters within the genome of the organism. Lipopolysaccharide is one of the most important cell-surface polysaccharides, as it plays a key structural role in outer membrane integrity, as well as being an important mediator of host-pathogen interactions. The genetics for the biosynthesis of the so-called A-band (homopolymeric) and B-band (heteropolymeric) O antigens have been clearly defined, and a lot of progress has been made toward understanding the biochemical pathways of their biosynthesis. The exopolysaccharide alginate is a linear copolymer of ß-1,4-linked D-mannuronic acid and L-guluronic acid residues, and is responsible for the mucoid phenotype of late-stage cystic fibrosis disease. The *pel* and *psl* loci are two recently discovered gene clusters that also encode exopolysaccharides found to be important for biofilm formation. Rhamnolipid is a biosurfactant whose production is tightly regulated at the transcriptional level, but the precise role that it plays in disease is not well understood at present. Protein glycosylation, particularly of pilin and flagellin, is a recent focus of research by several groups and it has been shown to be important for adhesion and invasion during bacterial infection.[11]

## Pathogenesis



Pseudomonas infection of the hand

An opportunistic pathogen of immunocompromised individuals, *P. aeruginosa* typically infects the pulmonary tract, urinary tract, burns, wounds, and also causes other blood infections.[12] It's the most common cause of burn and external ear infections, and is the most frequent colonizer of medical devices (e.g.catheters). *Pseudomonas* can in rare circumstances cause community acquired pneumonias,[13] as well as ventilator-associated pneumonias, being one of the most common agents isolated in several studies.[14] Pyocyanin is a virulence factor of the bacteria and has been known to cause death in *C. elegans* by oxidative stress. However, research indicates that salicylic acid can inhibit pyocyanin production.[15] One in ten hospital-acquired infections are from *Pseudomonas*. Cystic fibrosis patients are also predisposed to *P. aeruginosa* infection of the lungs. *P. aeruginosa* may also be a common cause of "hot-tub rash" (dermatitis), caused by lack of proper, periodic attention to water quality. The most common cause of burn infections is *P. aeruginosa*. *Pseudomonas* is also a common cause of post-operative infection in radial keratotomy surgery patients. The organism is also associated with the skin lesion ecthyma gangrenosum.

*P. aeruginosa* uses the virulence factor exotoxin A to ADP-ribosylate eukaryotic elongation factor 2 in the host cell, much as the diphtheria toxin does. Without elongation factor 2, eukaryotic cells cannot synthesize proteins and necrose. The release of intracellular contents induces an immunologic response in immunocompetent patients.

With plants, *P. aeruginosa* induces symptoms of soft rot with *Arabidopsis thaliana* (Thale cress) and *Letuca sativa* (Lettuce) [16][17]. It is a powerful pathogen with *Arabidopsis*[18] and with some animals: *Caenorhabditis elegans*[19][20], *Drosophila*[21] and *Galleria mellonella*[22]. The associations of virulence factors are the same for vegetal and animal infections[16][23].

### Quorum sensing

Regulation of gene expression can occur through cell-cell communication or quorum sensing (QS) via the production of small molecules called autoinducers. QS is known to control expression of a number of virulence factors. Another form of gene

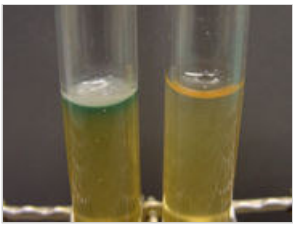
regulation which allows the bacteria to rapidly adapt to surrounding changes is through environmental signaling. Recent studies have discovered that anaerobiosis can significantly impact the major regulatory circuit of QS. This important link between QS and anaerobiosis has a significant impact on production of virulence factors of this organism.[11]

### Biofilms

The achievements of medical care in industrialised societies are markedly impaired due to chronic opportunistic infections that have become increasingly apparent in immunocompromised patients and the ageing population. Chronic infections remain a major challenge for the medical profession and are of great economic relevance because traditional antibiotic therapy is usually not sufficient to eradicate these infections. One major reason for persistence seems to be the capability of the bacteria to grow within biofilms that protect them from adverse environmental factors. *Pseudomonas aeruginosa* is not only an important opportunistic pathogen and causative agent of emerging nosocomial infections, but can also be considered a model organism for the study of diverse bacterial mechanisms that contribute to bacterial persistence. In this context the elucidation of the molecular mechanisms responsible for the switch from planctonic growth to a biofilm phenotype and the role of inter-bacterial communication in persistent disease should provide new insights in *P. aeruginosa* pathogenicity, contribute to a better clinical management of chronically infected patients and should lead to the identification of new drug targets for the development of alternative anti-infective treatment strategies[11].

## Diagnosis

Depending on the nature of infection, an appropriate specimen is collected and sent to the bacteriology laboratory for identification. First, a Gram stain is performed, which should show G negative, rods with no particular arrangement. Then, if the specimen is pure, the organism is grown on MacConkey agar plate to produce colorless colonies (as it doesn't ferment lactose), but if the specimen is not pure, then the use of a selective plate is essential. Cetrimide agar has been traditionally used for this purpose. When grown on it, *P. aeruginosa* expresses the exopigment pyocyanin, which is blue-green in color, and the colonies will appear flat, large, and oval. It also has a characteristic fruity smell. *P. aeruginosa* is catalase, oxidase, nitrase, and lipase positive. When grown on TSI medium it has a K/K/g-/$H_2S$- profile, meaning that the medium will not change color. Finally, serology could help which is based on H & O antigens.



Production of pyocyanin, water-soluble green pigment of Pseudomonas aeruginosa. (left tube)

## Treatment

*P. aeruginosa* is frequently isolated from non-sterile sites (mouth swabs, sputum, and so forth) and under these circumstances, it often represents colonisation and not infection. The isolation of *P. aeruginosa* from non-sterile specimens should therefore be interpreted cautiously and the advice of a microbiologist or infectious diseases physician should be sought prior to starting treatment. Often no treatment is needed.

When *P. aeruginosa* is isolated from a sterile site (blood, bone, deep collections), it should be taken seriously and almost always requires treatment.

*P. aeruginosa* is naturally resistant to a large range of antibiotics and may demonstrate additional resistance after unsuccessful treatment, particularly through modification of a porin. It should usually be possible to guide treatment according to laboratory sensitivities, rather than choosing an antibiotic empirically. If antibiotics are started empirically, then every effort should be made to obtain cultures and the choice of antibiotic used should be reviewed when the culture results are available.

Antibiotics that have activity against *P. aeruginosa* include:

- aminoglycosides (gentamicin, amikacin, tobramycin);
- quinolones (ciprofloxacin and levofloxacin but *not* moxifloxacin)
- cephalosporins (ceftazidime, cefepime, cefpirome, but *not* cefuroxime, ceftriaxone, cefotaxime)
- ureidopenicillins (piperacillin, ticarcillin: *P. aeruginosa* is intrinsically resistant to all other penicillins)
- carbapenems (meropenem, imipenem, but *not* ertapenem)
- polymyxins (polymyxin B and colistin)[24]
- monobactams (aztreonam)

These antibiotics must all be given by injection, with the exception of fluoroquinolones. For this reason, in some hospitals, fluoroquinolone use is severely restricted in order to avoid the development of resistant strains of *P. aeruginosa*. In the rare occasions where infection is superficial and limited (for example, ear infections or nail infections) topical gentamicin or colistin may be used.

### Antibiotic resistance

*Pseudomonas aeruginosa* is a highly relevant opportunistic pathogen. One of the most worrisome characteristics of *P. aeruginosa* consists is its low antibiotic susceptibility. This low susceptibility is attributable to a concerted action of multidrug efflux pumps with chromosomally-encoded antibiotic resistance genes and the low permeability of the bacterial cellular envelopes. In addition to this intrinsic resistance, *P. aeruginosa* easily develops acquired resistance either by mutation in chromosomally-encoded genes or by the horizontal gene transfer of antibiotic resistance determinants. Development of multidrug resistance by *P. aeruginosa* isolates requires several different genetic events that include acquisition of different mutations and/or horizontal transfer of antibiotic resistance genes. Hypermutation favours the selection of mutation-driven antibiotic resistance in *P. aeruginosa* strains producing chronic infections, whereas the clustering of several different antibiotic resistance genes in integrons favors the concerted acquisition of antibiotic resistance determinants. Some recent studies have shown that phenotypic resistance associated to biofilm formation or to the emergence of small-colony variants may be important in the response of *P. aeruginosa* populations to antibiotics treatment.[11]

### Prevention

Medical Grade honey may reduce colonization of many pathogens including pseudomonas aeruginosa.[25] Probiotic prophylaxis may prevent colonization and delay onset of pseudomonas infection in an ICU setting.[26] Immunoprophylaxis against pseudomonas is being investigated. [27]

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## See also

- Bacteriological water analysis
- Contamination control
- Nosocomial infection

## External links

- www.pseudomonas.com, the Pseudomonas genome database
- Migula's Systematic Bacteriology **(German)**
- Spotlight on Pseudomonas